Census of Marine Life: Turning Concept into Reality
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Ecosystem effects of a quickly developed fishery: trends in biomass of demersal resources of Senegal and Guinea.

By Martial Laurans[1], Aboubacar Sidibe[2], Emmanuel Chassot[1] and Didier Gascuel[1]

Fisheries in West Africa have quickly grown during the last decades. From a scientific point of view, this evolution represents a very interesting case study which allows an analysis of ecosystem changes under such growing fisheries. Only biomass trends for Senegal and Guinean demersal resources are considered from commercial statistics as well as scientific data surveys. Time abundance series are estimated since the 70's using GLM methods, on one hand for a selection of various stocks and on the other hand for total biomass splited into trophic levels and ecological communities. Total biomass has been decreased, the most important decreases were observed for the upper trophic level species and for coastal communities. As a response of species to the fishing pressure, the trophic level is emphasized.

Keywords : ecosystem, trophic-level, typology

1 : ENSA, Departement Halieutique, 65 rue de Saint Brieuc, CS 84215, 35042, Rennes cédex, France. [Tel] : + 33 2 23 48 54 56, fax : + 33 2 23 48 55 35, email : laurans@roazhon.inra.fr]

2: CNSHB, Centre National des Sciences Halieutiques de Boussoura, Conakry, Guinée.

Introduction

Senegal and Guinea are two countries of West Africa where fishing activities represent a very important economic weight (Foucault et al, 1994; Diallo et Fautrel, 2000). In Senegal, artisanal and industrial fisheries (PA and PI) develop together (Thiam and Gascuel, 1994), with a demersal fish production from about 60,000 tons in 1970 to 350,000 tons in 1990. If the industrial landing was more important, in the 1970s, this is no longer true today. Before 1985, Guinean artisanal fishery (PA) was undeveloped and coastal resources appeared almost unexploited; only foreign trawlers exploited the Guinean shelf (Sidibé, 1998). Since 1985, the PA is fully developed and mainly exploits the coastal resources of the sciaenid community.

In this context, where we know the quick fishing development, we want to see the impact on the ecosystem. From statistics and scientific survey data, we estimate abundance time series in both these countries concerning species, communities or trophic groups. Various methods are applied in function of the available data. We focused on the most targeted species: in Senegal, the white grouper (*Epinephelus aeneus*), the bluespotted seabream (*Sparus caeruleostictus*), the red pandora (*Pagellus bellottii*), the west African goatfish (*Pseudupeneus prayensis*), the lesser African threadfin (*Galeoides decadactylus*) and in Guinea, the lesser African threadfin, the bobo croaker (Pseudotolithus elongatus), the longneck croaker (*Pseudotolithus typus*), the cassava croaker (*Pseudotolithus senegalensis*) and the catfish (*Arius spp*).

This study takes place in the FIAS (Fisheries Information and Analyse System project) project where one of the modules concerns the analysis of fishing and scientific data in order to establish a diagnostic of the state of marine resources in West Africa (Mauritania, Senegal, Gambia, Guinea Bissau, Guinea and Cape Verde).

Material and methods

In the countries, the data does not cover the same period. In Senegal, the statistics takes place since 1972 for the national industrial fishery and 1983 for the foreign trawlers. Data for the artisanal fishery are exhaustively known since 1981. All these data are collected by the CRODT (Oceanographic Research Centre of Dakar-Thiaroye). In aaddition, the CRODT together with the IRD (French Research Institute for the Development) carried out scientific trawl surveys. Some of these surveys have been performed between 1971 and 1974 and between 1986 and 1995. In Guinea, the situation is quite different; the statistic system has begun in 1995 for both the industrial and artisanal fisheries. Scientific trawl surveys took place between 1985 and 1998 by two research entities, the CNSHB (National Centre of Fisheries Science of Boussoura in Guinea) and IRD.

The artisanal fishery (PA) is only composed by pirogues, (their size depends on the “metier” practised). PA data (effort and production) spring from an extrapolation by “metier” (Laurec and Le Guen, 1981). This extrapolation was made from sampling activities (Ferraris et al, 1994 for Senegal). By “metier”, the effort unit is a fishing day for a pirogue.

In Senegal, trawlers meanly compose the industrial fishery. There is an observer on board of each foreign boat; who collects all data on effort, boat position landing. For the national vessels, the informations are obtained when they land their catch at the harbour. In Guinea, one part of the fleet (foreigners and national) is exhaustively checked every quarter (effort, production, position). Hence, the total catches are extrapolated.

From these data, three types of methods are used for analysis: a stock assessment by the surplus production model, age structured model, and GLM (Global Linear Model) method.

The surplus production model has been applied in a previous work (Laurans et al, 2001; Sidibé et al, 2001); this approach allows to compare the coherence of different abundance indices series (CPUE of different "metier" or fleet segment, indices from surveys…). Some of the results are used in this paper. From the effective efforts for each species, the fishing pressure increase can be estimated. Furthermore, the total biomass can be estimated too (*ibed*).

Stock analysis by age structured model requires precise data as length frequencies. For a given species, age strength and total biomass with the VPA can be estimated. However, in Guinea, as a real cohort is missing, the analysis is only carried out on pseudocohorts. Hence, only total biomass series are estimated for the Senegal (Gascuel and Laurans, 2002).

Abundance indices by species are obtained by linear generalized model (GLM). This method is applied to scientific catch data per haul (Gascuel and Laurans, 2001;Laurans and Gascuel, 2001; Sidibé et al, 2002) and to Senegalese statistics of industrial trawler monthly CPUE per boat and area. This method was first applied to statistics by Gascuel and Thiam (1994) for foreign and Senegalese trawlers. We later worked on foreign trawler's data between 1983 and 1998, where different factors as year, season, depth and fishing zone were tested (Laurans et al, 2002).

In Senegal, all the available time series (total biomass by surplus production and structural model, abundance index by GLM method) not cover the same period. A synthetic index was calculated to get a longer time series of abundance. Therefore, standardization is carried out taking as reference the series obtained from the structural model. For each series, a coefficient "a" (1) is calculated to fit the reference series. Then, the series are homogenized using the coefficient a. The synthetic index is the annual mean of all standardized series.

$$a = Sum_{ref}(IA_i, IA_{(i+j)}) / Sum_{series}(IA_i, IA_{(i+j)}) \qquad (1)$$

i is the first common year and i+j the last common year between the reference($_{ref}$) series and the series ($_{series}$) to standardize.

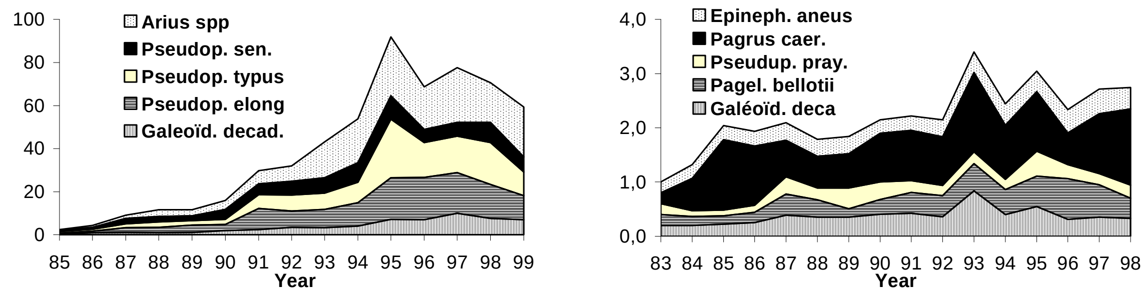
In the scientific trawl survey, all the species caught are well identified and counted. So, we cluster the haul catches by community and trophic group. We work on three communities, the Sciaenid, the Sparid and the Lutjanid (Longhurst, 1966; Domain, 2000). By community, three trophic groups are created, the first contains species with the trophic level between 3 and 3.5, the limits of the second are 3.5 to 4 and the third 4 to 4.5. The majority of species trophic level comes from the internet site *http://www.fishbase.org*. To analyse these data, GLM method is used and the factors year, season and depth are tested. The result tables are presented in annexe and abundance indices on graph.

On one hand, we compare the abundance evolution between species. Some variations are explained thanks to fishing activities and environment parameters. The abundance index by community is compared to its obtained by species. We want to see if the abundance variation of specie is representative of those of its community. Comparison of trophic groups is performed in order to visualize if there is a substitution of one group's abundance by another one.

On other hand, we test the existence of a relationship between the trophic level of species and their abundance. Here, we use the index calculated in the stock assessment analysis, namely the ratio B/Bv for the surplus production model (where B is the actual biomass and Bv is the virgin biomass estimation). The trophic level of species is presented versus the ratio B/Bv. By country, the correlation between the indicators is tested using the Spearman rank coefficients (Scherrer, 1984).

Results:

The effective efforts by species are obtained from the surplus production model (Figure 1). For the two countries, the effective efforts increase in different proportions; in Guinea, the exploitation is null for these coastal species in 1985. In Senegal, the fishing activity is already important in 1983. Since 1995; the situation appears stable in Senegal and a decrease is observed in Guinea. So, for Senegal, during the fifteen years, the effort has been multiplied by 2.5 and in Guinea the increase is far more important.



a b

Figure 1: Effective effort (arbitrary unit) by species from Guinea (a) and Senegal (b).

The evolution of the total biomass estimated by the surplus production model is clear (Figure 2). In the two countries, the decrease is notable, minus 75% in Senegal for 15 years and minus 70% in Guinea. Depending on the species, the decrease is more or less important. These trends are mainly explained by the increase of the fishing effort.

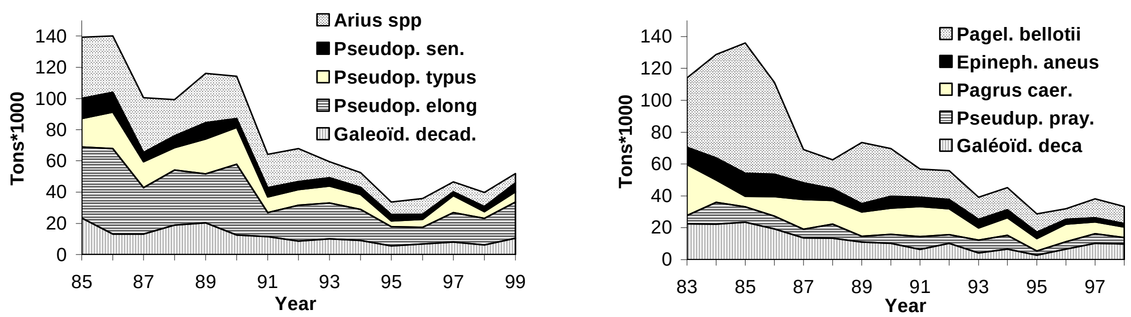


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Figure 2: Total biomass by species from surplus production model, Guinea (a) and Senegal (b).

To reason of clarity, the results by species we have obtained by the structural model and the GLM method will be not exposed. Indeed, these results are closed to the surplus production results and are used in the next analysis.

In Senegal, the synthetic index is based on various abundance estimations. In order to understand well the transformation, the abundance curves used for the white grouper and the synthetic index that we estimate are shown in figure 3. For reasons of readability, the synthetic curves are presented in two graphs. Indeed, the red pandora and the African threadfin abundance seems to increase in a first time until 1985, then the biomass decreases (Figure 4a). For the three others species, we can say that the biomass show a decrease trend between 1971 and 1999 (Figure 4b).

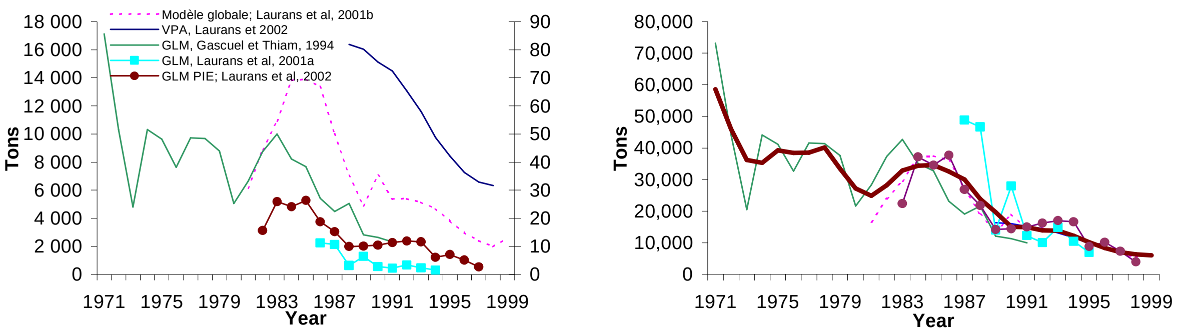

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Figure 3: a: Different abundance curves of thiof. b: The different abundance curves standardized and the sunthétic curve in bold.

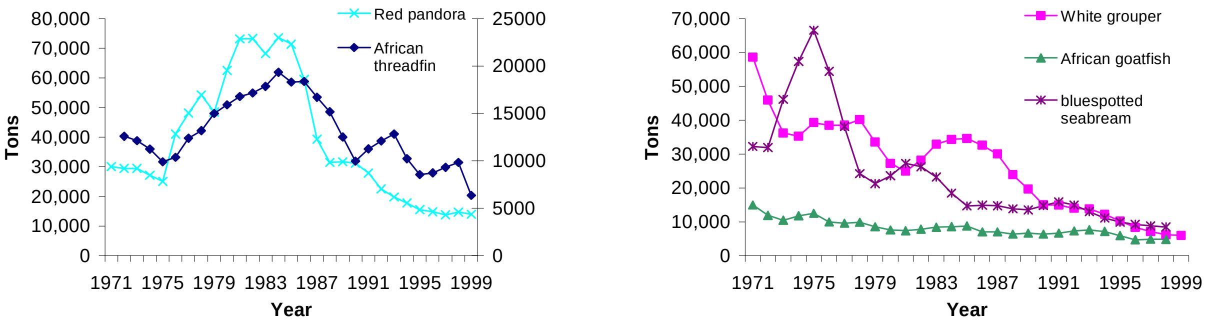

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Figure 4: Synthetic curves of Senegalese species.

The results of the abundance evolution for communities or trophic groups based on surveys are not significant in Senegal whereas in Guinea the opposite is true (annexe 1), except for the lutjanid community. In Guinea, the decrease of the Sparid community is more important than Scianid Community (Figure 5a). Indeed, the decrease between the beginning of the period and the end is about 75% to the Sparid community and only 45% to the Sciaenid. We can note for the Sparid community, an isolated increase of abundance during the years 1993 and 1994, whereas for the sciaenid the abundance increases since 1994. Except in 1993 and 1994 for the Sciaenids, the diagnosis (Figure 5b) is less pessimistic for the community than for some exploited species belonging to the community.

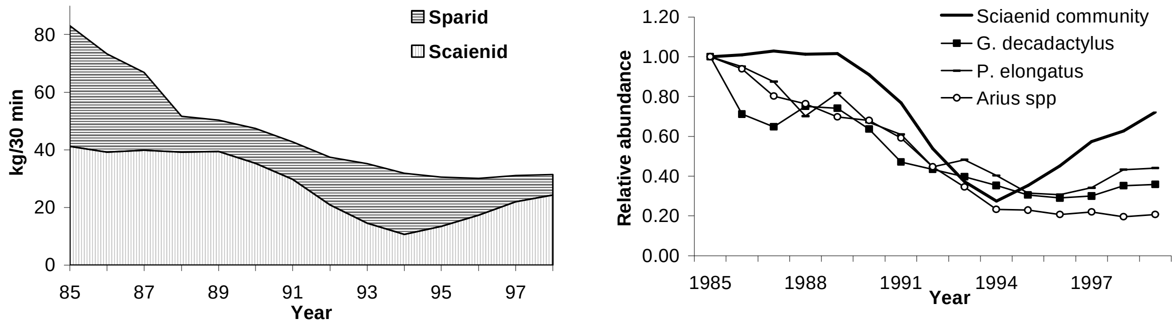

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Figure 5: a: Abundance of Sparid and Sciaenid communities. b: Relative abundance of Sciaenid community compared to relative abundance to species belonging to it.

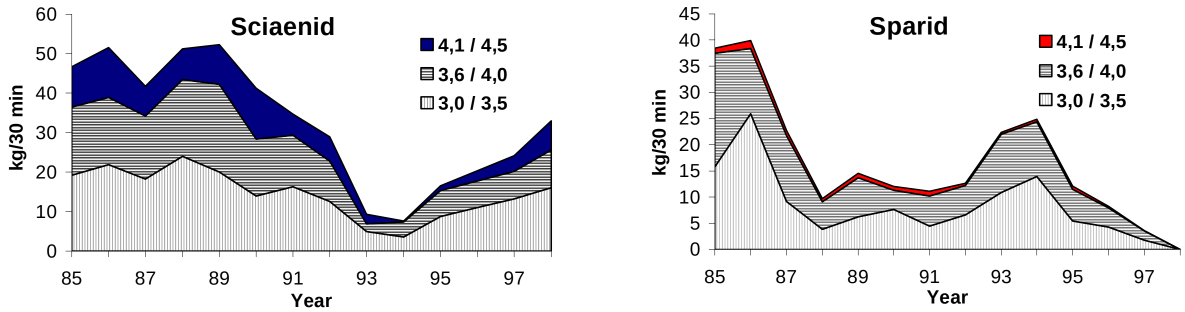

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Figure 6: a: Abundance of trophic group for the sciaenid community. b: Abundance of the trophic group for the Sparid community.

The abundance evolution by trophic group shows two important points. In terms of abundance, we don’t observe, hierarchical modification of trophic groups (Figure 6). This observation is true for the two communities. But in the Sciaenid community that is coastal one, the higher trophic group has the most important abundance decrease. This observation is not true in the Sparid community, localised more deeper.

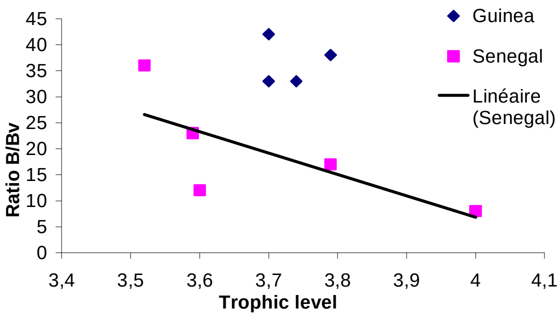

Figure 8: Trophic level of species versus its ratio B/Bv estimated by the surplus production model in Guinea and Senegal.

The relationship between the trophic level and the ratio B/Bv is not clear in Guinea. Indeed, the species that we studied in Guinea have close trophic levels. But, in Senegal, we observe a correlation ($r2=0.9$ and $p<0.025$). When the exploitation is intense, it seems that the species with low trophic levels are less affected.

Discussion

In the present study, we have not followed the same species in the 2 countries, except the African threadfin. In fact, the environmental characteristics of Senegal and Guinea continental shelf (Domain, 1980 and 2000) explain that fisheries don't target the same species. In Guinea, the continental shelf is not very deep and terrigenous supplies are important due to a rain season. So, the Guinean shore is characterised by a turbid water where the Sciaenid community is prominent. Then, a great majority of demersal catches is composed by the Sciaenid community, so the statistics of these species are more precise. Furthermore, the surveys performed between 1985 and 1998 mainly cover the coastal community. Estimation of abundance series for species living further from the coast turns more difficult. At the opposite, the landing of Sparid community species is more important in Senegal. Then, this study targets species that have an economic weight and require a quick management. It will be interesting to take in account more species for the next analysis.

Two reasons may explain the increase of the effective effort. One of the reasons is the increase of the number of pirogues in PA and the number of vessels in PI in each country (Lesnoff, 2000, Thiam and Gascuel, 1994). This point is more important in Guinea; the politic change in 1984 has reduced state intervention in the economy (Chavance 2000) and the artisanal fishing activities have developed. The second reason, in these countries as in others, is that the fishing power has highly increased (Gascuel, 1993; Laurec, 1977): first the motorization of the pirogue in PA, then the use of electronic material. This last point becomes important in PA with the use of GPS.

In the study, we have only shown the total biomass evolution (Figure2). In a fishery, it is quite normal that the biomass decreases under exploitation. But, in parallel, catches, after an increasing period have been decreasing for few years in Senegal; in Guinea the decrease begins. So for several species, the overexploitation is known (Laurans et al, 2002; Sidibe et al, 2002). The decrease of total biomass (80 to 90% for the white grouper and the red pandora) is huge. It is a strong element in surexploitation diagnostic. Some important economic (and cultural) species have decreased in a such proportion that consequent sustainability exploitation can't be supported. The fishing impact on the ecosystem primary occurs on the target species.

The synthetic indexes estimated in longer period than the other bring us further information. For the red pandora and the African threadfin (Figure 5a), we observe until 1985 an increase of the abundance. A first reason can explain this situation: the fishermen did not target these 2 species until the 70's. So, the apparent increase could be an artefact due to the fact that indexes for this period are based on commercial CPUE. Secondly, it is possible that environmental parameters would have been very positive for the larval survival. Caverivière (2002) show that the explosion of abundance for some species at the end of the seventeen is the consequent of a good larval survival.

The estimation of a synthetic index is interesting in various cases: when you have some results that don't cover the same period; when the base data are lost, you can't complete a time series (it is quite frequent); when in a long period the data are not homogenous to apply the same method. In the studied countries, these situations are not uncommon.
Here, this index allows to see for Senegalese species their abundance trend. The fishing impact is real. In order to enhance fishing management, these evolutions must be taken in account. This type of index is one element to answer the project requirements, that is: what about the state of marine resources?

The work on the community gives us some interesting results. The species that are targeted by fishing activities show a decrease biomass more important than the whole community (Figure 5b). Within the community some compensation seems to exist between target and no target species. So, the community has a more important buffer power than the target species. Blanchard (2001) shows the equivalent in European fisheries. Moreover, under the fishing pressure, the abundance decrease of high trophic group is equivalent or superior to the low trophic group. Thus, it would seem that the high trophic group or high trophic level species are more sensitive to fishing activities. This last point is completed by the correlation that we observe in Senegal between the ratio B/Bv and the trophic level (Figure 7). In multispecific fisheries like in Senegal, the species with high trophic level show the most important abundance decrease.

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Annexe 1: Fitting of GLM model(Generalized Linear Model)

Model: CPUE-Ecological Community ~ ibat+zone+an, family=gaussian(log)

Communauté à Sciaenidés :

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	66 310 518		
ibat	5	11 830 532	2 285	54 479 987	105.8	0.0000 ***
zone	2	442 415	2 283	54 037 571	9.9	0.0001 ***
an	12	3 272 906	2 271	50 764 665	12.2	0.0000 ***

Communauté à Sparidés

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			1 656	10 365 109		
ibat	3	608 063	1 653	9 757 046	35.9	0.0000 ***
zone	2	367 726	1 651	9 389 320	32.6	0.0000 ***
an	12	99 085	1 645	9 290 235	2.9	0.0077 ***

Sciaenidés Community:

Trophic group (3-3.5)

Model: CPUE ~ ibat+zone+an, family=gaussian(log)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	17 764 742		
ibat	5	2 017 938	2 285	15 746 804	60.85	0.0000 ***
zone	2	157 640	2 283	15 589 164	11.88	0.0001 ***
an	12	527 307	2 271	15 061 857	6.626	0.0000 ***

Trophic group (3.5-4)

Model: CPUE ~ ibat+zone+an, family=gaussian(log)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	10 312 935		
ibat	5	937 830	2 285	9 375 105	47.98	0.0000 ***
zone	2	58 471	2 283	9 316 634	7.479	0.0001 ***
an	12	438 898	2 271	8 877 737	9.356	0.0000 ***

Trophic group (4-4.5)

Model: CPUE ~ ibat+zone+an, family=gaussian(log)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	6 462 792		
ibat	5	1353557	2 285	5 109 235	132	0.0000 ***
zone	2	65 120	2 283	5 102 723	15.87	0.0001 ***
an	12	443 914	2 271	4 658 809	18.03	0.0000 ***

Sparidés Community:

Trophic group (3-3.5)

Model: CPUE ~ ibat+zone+an, family=gaussian(log)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	15 337 579		
ibat	5	1 951 637	2 285	13 385 942	69.92	0.0000 ***
zone	2	180 037	2 283	13 205 905	16.12	0.0000 ***
an	12	529 832	2 271	12 676 073	7.910	0.0000 ***

Trophic group (3.5-4)

Model: CPUE ~ ibat+zone+an, family=gaussian(log)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	5 918 436		
ibat	5	552 955	2 285	5 365 481	60.74	0.0000 ***
zone	2	172 875	2 283	5 192 607	28.48	0.0001 ***
an	12	219 032	2 271	4 973 575	6.015	0.0000 ***

Trophic group (4-4.5)

Model: CPUE ~ ibat+zone+an, family=gaussian(log)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			2 290	23 353		
ibat	5	868.7	2 285	22 485	21.85	0.0000 ***
zone	2	252.9	2 283	22 232	9.540	0.0001 ***
an	12	512.7	2 271	21 719	3.224	0.0000 ***